FOUR-IN PUMP

Technical Field

The present invention relates to a four-in pump where pistons respectively arranged in four volume chambers perform pumping motion, and more particularly to a four-in pump, wherein four eccentric shafts perform eccentric rotational motion using gearing means of a gear box arranged between the first and the second cylinder blocks, and pistons respectively mounted on the eccentric shafts perform inscribed eccentric circular motion with different speeds each other at the volume chambers in the first and the second cylinder blocks.

Background Art

The patent application No.2001-77842(field on December 10, 2001) discloses "Volume type pump having a pair of volume chambers and assembling method thereof".

According to the above volume type pump, a diameter of an eccentric shaft is possibly made sufficiently large for enduring twisting stress, and the side of the piston closely sticks to the inner wall of the cylinder so that pumping material in the inside of the cylinder does not flow into the inside of the piston, and lubricant in the inside of the piston does not flow into the inside of the cylinder while the piston is performing inscribed eccentric rotational motion within the cylinder with a nut for applying pressure on the piston mounted on a free end of the eccentric shaft.

But, the volume type pump has inferiorities such as pulsation and severe vibration due to inscribed eccentric rotational motion of the piston.

Disclosure of Invention

It is, therefore, an object of the present invention to provide a four-in pump capable of canceling pulsation and vibration by the construction such that four eccentric shafts perform eccentric rotational motion by gearing means of a gear box arranged between the first and the second cylinder blocks, and pistons respectively mounted on the eccentric shafts perform inscribed eccentric circular motion with different speeds each other at the

volume chambers in the first and the second cylinder blocks.

The foregoing and other objects and advantages are realized by providing a four-in pump including: a gear box being arranged between a first and a second cylinder blocks; a gearing means arranged within the gear box being connected with a driving shaft of a motor; four eccentric shafts being mounted for possibly performing eccentric rotational motion, on the gearing means, respectively; and four pistons respectively mounted on the eccentric shafts being arranged on an upper and a lower volume chambers of the first cylinder block and on an upper and a lower volume chambers of the second cylinder block, respectively.

The gearing means consists of a driving gear mounted on a driving shaft and a first and a second driven gears cooperated with the driving gear.

The first driven gear has a first eccentric shaft for operating a first piston and a third eccentric shaft for operating a third piston, while the second driven gear has a second eccentric shaft for operating a second piston and a fourth eccentric shaft for operating a fourth piston.

A center point of rotation of the driving gear is displaced as much as a predetermined length to a direction of a vertical axis from a reference center point, and center points of rotation of the driven gears are also displaced as much as an eccentric distance of the driving gear to a direction of a vertical axis from reference center points.

In case that the driving gear and the driven gear are cooperated each other with their center points displaced, while the first and the second pistons perform eccentric rotational motion of internally touching the volume chamber of the cylinder block, a rotational speed of the first eccentric shaft at the first quadrant becomes relatively faster than a rotational speed of the first piston, so that a nose of the first eccentric shaft is rotated first from an upper dead point to the horizontal axis before the first piston.

In case that the driving gear and the driven gear are cooperated each other with their center points displaced, while the first and the second pistons perform eccentric rotational motion of internally touching the volume chamber of the cylinder block, the second eccentric shaft at the second quadrant is rotated more slowly than an average speed of the second piston.

The first and the third eccentric shafts are fit in the first driven gear so

that each end of them faces each other, and fixed by a key and completely fixed in the first driven gear by means of a plurality of bolts.

The second and the fourth eccentric shafts are fit in the second driven gear so that each end of them faces each other, and fixed by a key and completely fixed in the second driven gear by means of a plurality of bolts.

The driving gear and the two driven gears are helical gear capable of vertically cooperating each other, for transferring power to the eccentric shaft vertically arranged with respect to the driving shaft.

The two driven gears are reversed in their gear tooth directions.

For the driving gear and the driven gear, a worm and worm gear may be used.

The piston comprises: the eccentric shaft possibly performing relative rotational motion with respect to a cylindrical body by means of a thrust bearing and a ball bearing; an outer peripheral surface of the cylindrical body being coated by elastic rubber; a bolt passing through a front cap being joined to a tap hole of the eccentric shaft; a spring being arranged between the front cap and the ball bearing; a front seal being arranged in front of the front cap, for sealing the cylindrical body; a rear cap being arranged at an opening in a rear part of the body; and a sealing member of a circular shape being arranged in the rear cap.

The above object is realized by providing a four-in pump according to another aspect of the present invention, having: a gear box being arranged between a first and a second cylinder blocks; a gearing means arranged within the gear box being connected with a driving shaft of a motor; four eccentric shafts being mounted for possibly performing eccentric rotational motion, on the gearing means, respectively; pistons respectively mounted on the eccentric shafts being arranged on an upper and a lower volume chambers of the first cylinder block and on an upper and a lower volume chambers of the second cylinder block, respectively; the four-in pump includes: the upper piston having a bearing housing arranged in its piston housing; a bearing being mounted in an inside of the bearing housing; the eccentric shaft being fit in the bearing; an inner peripheral surface of the piston housing being of an elliptical shape; and an outer peripheral surface of the bearing housing being of an elliptical shape, so that a gap is formed

between the piston housing and the bearing housing.

A plurality of elastic O-rings is mounted on the outer peripheral surface of the bearing housing, for compensating for a part spaced by a gap.

Construction and operation of the lower piston are the same as those of the upper piston, and further, construction and operation of an upper piston and a lower piston in the second volume chamber are also the same as those of the upper piston in the first cylinder block.

The gearing means includes: the driving gear and the driven gear possibly cooperating each other around the rotational central axis without eccentricity, and a rotational speed of the eccentric shafts possibly changing through change of power transferring rate by change of a gear module.

The above object is realized by providing a four-in pump according to still another aspect of the present invention, including: a gear box being arranged between a first and a second cylinder blocks; a gearing means arranged within the gear box being connected with a driving shaft of a motor; two shafts being mounted on the gearing means, respectively; and pistons respectively mounted on the shafts being arranged on an upper and a lower volume chambers of the first cylinder block and on an upper and a lower volume chambers of the second cylinder block, respectively.

The driving gear and the driven gear of the gearing means are cooperated, so that the shafts mounted on the driven gears could be rotated and taper parts having the same rotational axis lines as the rotational central axis lines of the shafts are formed at both ends of the shafts, and eccentric pistons displaced with respect to the rotational central axis lines of the shafts are mounted on the taper part.

The shafts include: the taper parts on which the eccentric pistons are mounted so that eccentric positions of the pistons could be arbitrarily adjusted and operation order of the eccentric pistons could be arbitrarily set.

An inner peripheral surface of the piston housing in the eccentric pistons is of an elliptical shape and an outer peripheral surface of the bearing housing mounted on the inner peripheral surface of the piston housing is of an elliptical shape, so that a gap is formed between the inner peripheral surface of the piston housing and the outer peripheral surface of the bearing housing.

Brief Description of Drawings

The above objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig.1 is a perspective view showing an embodiment of a four-in pump according to the present invention;

Fig.2 is a cross-sectional view schematically showing each element in a cross-section taken along line A-A in Fig.1 in order to describe operation of a four-in pump according to the present invention;

Fig.3 is a schematic view showing a driving gear and a driven gear only in order to describe eccentricity of the driving gear and the driven gear in a four-in pump of the present invention;

Fig.4 is a drawing showing a driven gear and a piston side by side, in order to describe principle that a piston is operated by eccentricity of a driven gear;

Fig.5a and 5b are schematic views showing operation of a piston by eccentricity of a gear;

Fig.6 is a drawing showing problems occurring in case of there being no eccentricity in a volume type pump of a related art;

Fig.7 is a partial, cross-sectional view of a case that an eccentric shaft is mounted on a driven gear in a four-in pump;

Fig.8 is a cross-sectional view showing an example of a piston according the present invention;

Fig.9 is a cross-sectional view showing another example of a piston according the present invention;

Fig.10 is a cross-sectional view taken along line A-A of Fig.12 showing a four-in pump according to another embodiment of the present invention;

Fig.11 is an exploded, perspective view of a piston of Fig.10;

Fig.12 a sided, cross-sectional view schematically showing a four-in pump according to another embodiment of the present invention;

Fig.13 is a drawing showing that a bearing housing is moved to an inner peripheral surface of a piston housing as much as a gap when a piston operates;

Fig.14 is a sided, cross-sectional view schematically showing a four-in pump according to still another embodiment of the present invention; and

Fig.15 is a cross-sectional view taken along line B-B of Fig.14 showing an eccentric piston.

Best Mode for Carrying Out the Invention

A preferred embodiment of the present invention will now be described with reference to the accompanying drawings.

Referring to Fig.1 and Fig.2, a four-in pump according to the first embodiment of the present invention, includes: a gear box 21 being arranged between a first and a second cylinder blocks 100 and 200; a gearing means 1 arranged within the gear box 21 being connected with a driving shaft 13 of a motor 11; four eccentric shafts ES1 through ES4 being mounted on the gearing means 1, respectively; and four pistons 120, 160, 220, 260 respectively mounted on the eccentric shafts ES1 through ES4 being arranged on an upper and a lower volume chambers 110 and 150 of the first cylinder block 100 and on an upper and a lower volume chambers 210 and 250 of the second cylinder block 200.

In Fig.1, the reference numeral 500 stands for an absorption pipe connected to absorption ports of the first and the second cylinder blocks 100 and 200, and the reference numeral 600 stands for a discharging pipe connected to discharging ports of the first and the second cylinder blocks 100 and 200.

The gearing means, as shown in Fig.2, consists of a driving gear 31 mounted on a driving shaft 13 of a motor, and the first and the second driven gears 41 and 51 cooperated with the driving gear 31.

The first driven gear 41 has a first eccentric shaft ES1 for operating a first piston 120 and a third eccentric shaft ES3 for operating a third piston 220, while the second driven gear 51 has a second eccentric shaft ES2 for operating a second piston 160 and a fourth eccentric shaft ES4 for operating a fourth piston 260.

With such construction, as shown in Fig.2, when the first and the second pistons 120 and 160 are positioned at a lower dead point, the third and the fourth pistons 220 and 260 are positioned at an upper dead point.

Referring to Fig.3, a center point O1 of rotation of the driving gear 31 is displaced as much as a predetermined length 'd' to a direction of a vertical axis 'y' from a reference center point P1, and center points O2 and O3 of rotation of the driven gears 41 and 51 are also displaced as much as an eccentric distance 'd' of the driving gear 31 to a direction of a vertical axis 'y' from reference center points P2 and P3.

Operation of the pistons 120, 160, 220, 260 influenced by eccentricity of the driven gears 41 and 51 will be described with reference to Fig.4 in the following. Fig.4 shows a status that the first piston 120 reaches the lower dead point so that discharging of pumping material is completed in the upper volume chamber 110 of the first cylinder block 100, while the fourth piston 160 reaches the upper dead point so that discharging of pumping material is simultaneously completed in the lower volume chamber 250 of the second cylinder block 200. Also, at the moment, the second piston reaches the lower dead point so that pumping material is absorbed into the lower volume chamber 150 of the first cylinder block 100 while the third piston 220 reaches the upper dead point so that pumping material is absorbed into the upper volume chamber 210 of the second cylinder block 200.

Generally, in an object performing circular motion, its tangent velocity and acceleration reduce as an object gets apart from a center point while its tangent velocity and acceleration increase as an object approaches a center point. Namely, the first driven gear 41 cooperates with the driving gear 31 through the rotational center O2, so that angular acceleration increases when the first driven gear 41 passes through an arc interval ABC while angular acceleration decreases when the first driven gear 41 passes through an arc interval CDA. Therefore, when the first driven gear 41 passes through the arc interval ABC, rotational speed of the first eccentric shaft ES1 increases and rotational speed of the first piston 120 increases, so that pumping material is discharged fast into a discharging port 115 of the first cylinder block 100. Conversely, when the first driven gear 41 passes through the arc interval ABC, the second driven gear 51 is engaged with the driving gear 31 through the rotational center O3 at an arc interval GHE where an angular acceleration reduces, so that rotational speed of the fourth eccentric shaft ES4 reduces and rotational speed of the fourth piston 260 reduces,

whereby the angular speed of the fourth piston 260 gets relatively lower than that of the first piston 120. Resultantly, pumping material discharged into the discharging port 215 of the second cylinder block 200 is discharged relatively later than pumping material discharged into the discharging port 115 of the first cylinder block 100. At the moment, in absorption procedures by the second and the third pistons 160 and 210, absorption of pumping material by the second piston 160 is performed relatively later than absorption of pumping material by the third piston 210.

If the first and the second driven gears 41 and 51 are rotated further, absorption and discharging of pumping material by the pistons are performed conversely.

Operation principle of the first and the second pistons 120 and 160 in the first cylinder block 100 due to eccentricities of the driving gear 31 and the driven gears 41 and 51, will be described with reference to Fig.5a and Fig.5b in the following. In Fig.5a and 5b, the first and the second pistons 120 and 160 arranged in the first cylinder block 100, and the third and the fourth pistons 220 and 260 arranged in the second cylinder block 200 are the same in their construction and operation principle with only difference in their phase. Therefore, only operation relation between the first, the second pistons 120, 160 and the first, the second eccentric shafts ES1, ES2 arranged in the first cylinder block 100, will be described for convenience.

As described in Fig.4, in case that the driving gear 31 and the driven gears 41, 51 are displaced and cooperated, the whole speed of the pistons 120 and 160 does not change, but the angular velocities of the pistons 120 and 160 change for each point when the driven gears 41 and 51 are rotated one time.

Namely, when the first and the second pistons 120 and 160 perform eccentric rotational motion of internally touching the upper and the lower volume chambers 110 and 150 of the first cylinder block 100, namely from a status in Fig.5a to a status in Fig.5b, rotational speed of the first eccentric shaft ES1 gets relatively faster than rotational speed of the first piston 120 in the first quadrant F1, so that nose of the first eccentric shaft ES1 is rotated first from the upper dead point to the X2 axis before the first piston 120. Therefore, when reaching the point of 45° on the first quadrant F1, the first

piston 120 does not apply pressure on the inner peripheral surface of the upper volume chamber 110 of the first cylinder block 100, and the first piston 120 gets faster in its speed than the average speed, applying pressure on the pumping material in the first quadrant F1. Generally, the discharging pipe(not shown) connected to the discharging port 115 is installed higher than the absorption port 113, which is advantageous in discharging pumping material, resolving general problems occurring in case that the driving gear 31 and the driven gears 41, 51 are not displaced from the center.

Namely, as shown in Fig.6, in the volume type pump in which the first and the second pistons 420 and 430 are connected each other by means of the connecting frame 410, in case that the driving gear and the driven gear are not displaced from the center, when the first and the second pistons 420 and 430 pass through the first quadrant F1, there occurs a phenomenon that the crease part of the first and the second pistons 420 and 430 penetrate into the first quadrant F1 of the upper volume chamber 450 and the second quadrant F2 of the lower volume chamber 460. Therefore, while passing through the first quadrant F1 of the upper volume chamber 450 and the second quadrant F2 of the lower volume chamber 460, the first and the second pistons 420 and 430 may be destroyed or transformed by being given repulsive force from the cylinder block which is a rigid body.

Referring to Fig.5a and Fig.5b, when the first and the second pistons 120 and 160 perform eccentric rotational motion of internally touching the upper and the lower volume chambers 110 and 150 of the first cylinder block 100, namely from a status in Fig.5a to a status in Fig.5b, the second eccentric shaft ES2 is rotated relatively slower than the average speed of the second piston 160 in the second quadrant F2, which has the same effect as the above case that the first eccentric shaft ES1 is rotated relatively faster than the first piston 120 in the first quadrant F1, so that destruction of the second piston 120 is prevented and the discharging stroke of the first piston 120 is not disturbed.

Such principle is also applied when the first piston 120 passes through the third quadrant and the second piston 160 passes through the fourth quadrant.

Referring to Fig.7, the first and the third eccentric shafts ES1 and ES3

are fit in the first driven gear 41 so that each end of them faces each other, and fixed by a key 43, and completely fixed in the first driven gear 41 by means of a plurality of bolts 45.

The second and the fourth eccentric shafts ES2 and ES4 are also fit in the second driven gear 51 so that each end of them faces each other, and fixed by a key 53 and completely fixed in the second driven gear 51 by means of a plurality of bolts 55.

The driving gear 31 and the two driven gears 41, 51 are preferably a helical gear(generally, a twisting angle between a driving helical gear and a driven helical gear forms 45° so that power is transferred through an angle of 90°) capable of vertically cooperating each other, for transferring power to the eccentric shafts ES1, ES2, ES3, ES4 vertically arranged with respect to the driving shaft 13. The two driven gears 41 and 51 are reversed in their gear tooth directions. Also, for the driving gear and the driven gear, a worm and a worm gear may be used, without restrictions to those shown in the drawing.

As the first, the second, the third, and the fourth pistons 120, 160, 220, 260 according to the present invention, are the same in their construction and operation, description of the first piston 120 only will be made in its construction and operation with reference to Fig.8 for convenience.

The piston 120 according to the first embodiment of the present invention includes: an eccentric shaft ES1 being relatively rotated with respect to a cylindrical body 310 by means of a thrust bearing 301 and a ball bearing 302, an outer peripheral surface of the cylindrical body 310 being coated by elastic rubber 320, a bolt 340 passing through a front cap 330 being joined to a tap hole 435 of the eccentric shaft ES1, a spring 350 being arranged between the front cap 330 and the ball bearing 301, a front seal 360 being arranged in front of the front cap 330, for sealing the cylindrical body 310, a rear cap 370 being arranged at an opening 315 in a rear part of the body 310, a sealing member 380 of a circular shape being arranged in the rear cap 370.

The sealing member 380 performs relative motion with respect to a rear panel 105 of the cylinder block 100, for preventing pumping material in the inside of the volume chamber from flowing into the inside of the housing

310 and preventing grease in the inside of the housing from leaking out to the volume chamber of the cylinder block.

In the piston 120 having the foregoing construction, the bolt 340 has a spiral such that the bolt 340 being fastened further to the eccentric shaft ES1 when the eccentric shaft ES1 rotates, so that as the eccentric shaft ES1 rotates, the front cap 330 applies pressure on the spring 350, whereby the cylindrical body 310 is stuck further on the sealing member 380 of a circular shape and the rear panel 105 of the cylinder block 100 by being given force in an arrow direction 390.

Referring to Fig.9, a piston 120' according to the second embodiment of the present invention is appropriate for the large capacity-volume type pump whose volume chamber of the cylinder block and piston itself are large. The Piston 120' according to the second embodiment of the present invention is the same as the piston of the first embodiment in its construction except that a general shaft S having one single rotational axis line instead of the eccentric shaft is used and the cylindrical body 310' is arranged in the shaft S in an eccentric manner.

Referring to Fig.10 and Fig.11, a four-in pump according to the second embodiment of the present invention will be described in the following.

As the constructions of the upper and the lower pistons 120 and 160 arranged in the first cylinder block 100 is the same as those of the upper and the lower pistons 220 and 260 in the second cylinder block 200, construction of only one piston will be selected and described. Particularly, in Fig.10, the piston is shown by alternate long and short dash line in circular shape in order to emphasize a gap 'd' between the piston housing 121 and the bearing housing 130. Here, the upper piston 120, as described above, includes: the bearing housing 130 being arranged in the piston housing 121, the bearing 140 being mounted within the bearing housing 130, and the eccentric shaft ES1 being fit in the bearing 140.

The inner peripheral surface 122 of the piston housing 121 is of an elliptical shape and the outer peripheral surface 131 of the bearing housing 130 is of an elliptical shape, so that a gap 'd' is formed between the piston housing 121 and the bearing housing 130. Therefore, the piston housing 121

has a longer Y axis length in its inner diameter than an X1 axis, and the bearing housing 130 has a shorter Y axis length in its diameter than an X axis.

The gap 'd' should be changed depending on the size of the volume chamber and the piston in the cylinder block. Namely, in case that a vertical length between the rotational axis center of the upper piston 120 and the rotational axis center of the lower piston 160 is 96mm, the gap 'd' should be more than 1.3242mm, while in case that a vertical length between the rotational axis center of the upper piston 120 and the rotational axis center of the lower piston 160 is 120mm, the gap 'd' should be more than 1.062mm, and in case that the vertical length is 144mm, the gap 'd' should be more than 0.8862mm.

Also, a plurality of elastic O-rings 133 is mounted on the outer peripheral surface of the bearing housing 130, for compensating for a part spaced each other by the gap 'd', preventing alien substance from flowing into the gap 'd' between the inner peripheral surface of the piston housing 121 and the bearing housing 130. Also, a plurality of the O-rings is compressed when the outer peripheral surface of the bearing housing 130 is stuck on the inner peripheral surface of the piston housing 121.

With such construction, in the four-in pump according to the second embodiment of the present invention, as shown in Fig.13, when the piston 120 performs eccentric circular motion in the volume chamber 110 by means of the eccentric shaft ES1, the outer peripheral surface 131'(represented by alternate long and two short dashes line) of the bearing housing 130 is moved to an arrow direction as much as the gap 'd', so that the outer peripheral surface 131 of the bearing housing 130 is stuck on the inner peripheral surface 122 of the piston housing 121. By such effect, stress is not generated between the outer peripheral surface 122 of the piston housing 121 and the inner peripheral surface of the volume chamber 110, whereby problems of destruction and malfunction of the piston 120 are resolved. In Fig.13, the alternate long and two short dashes line stands for a virtual line on which the outer peripheral surface 131' of the bearing housing 130 is positioned in case that the outer peripheral surface 131' of the bearing housing 130 is not moved to the inner peripheral surface of the piston

housing 121.

Therefore, according to the four-in pump of the present invention, as shown in Fig.12, the driving gear G1 and the driven gears G2 and G3 could cooperate each other around the rotational central axis without eccentricity, and a rotational speed of the eccentric shafts ES1 through ES4 could be changed through change of power transferring rate by changing a module for the gears G1, G2, G3.

Though description has been made regarding the upper piston 120 only in the above, construction and operation of the lower piston 160 are the same as those of the upper piston 120, and further, construction and operation of an upper piston 220 and a lower piston 260 in the second volume chamber 200 are also the same as those of the upper piston 120 in the first cylinder block 100.

Referring to Fig.14, in case that size of the pump is large, more specifically, the shaft for rotating the piston is large, it is very difficult to process the eccentric shaft. Therefore, a four-in pump according to the third embodiment of the present invention includes: two shafts S1 and S2 without eccentricity being used instead of the four eccentric shafts of the second embodiment; the shafts S1 and S2 being rotated by cooperation of the driving gear G1 and the driven gears G2 and G3; taper parts 501, 502, 503, 504 having the same rotational axis lines as the rotational central axis lines of the shafts S1 and S2 being formed at both ends of the shafts S1 and S2. By such structure, the eccentric pistons EP1, EP2, EP3, EP4 displaced with respect to the rotational central axis lines X2, X3 of the shafts S1, S2 are mounted on the taper parts 501, 502, 503, 504.

The shafts S1 and S2 have the taper parts 501, 502, 503, 504 on which the eccentric pistons EP1, EP2, EP3, EP4 are mounted so that eccentric positions of the pistons could be arbitrarily adjusted and operation order of the eccentric pistons EP1, EP2, EP3, EP4 could be arbitrarily set, whereby pumping order could be arbitrarily adjusted. For example, pumping strokes of the four pistons could be circulated in such an order that the first eccentric piston EP1 mounted on the taper part 501 of the first and the second shafts S1, S2 performs absorption stroke first at the first volume chamber 510 in the first cylinder block C1, and then the fourth eccentric

piston EP4 arranged at the fourth volume chamber 513 in the second cylinder block C2 performs absorption stroke, and after that, the second eccentric piston EP2 arranged at the second volume chamber 511 in the first cylinder block C1 performs absorption stroke, and lastly the third eccentric piston EP3 arranged at the third volume chamber 512 in the second cylinder block C2 performs absorption stroke.

Referring to Fig.15, as the four eccentric pistons EP1, EP2, EP3, EP4 are the same in their construction and operation, the first eccentric piston EP1 only is shown in Fig.7 as a representative.

Like the upper piston of the first embodiment, the inner peripheral surface 611 of the piston housing 610 in the first eccentric piston EP1, is of an elliptical shape and the outer peripheral surface 621 of the bearing housing 620 mounted on the inner peripheral surface 611 of the piston housing 610 is of an elliptical shape, so that a gap 'd' is formed between the inner peripheral surface 611 of the piston housing 610 and the outer peripheral surface 621 of the bearing housing 620. Also, the bearing housing 620 is displaced with respect to the central axis O1 as much as the rotational axis X2, so that the piston housing 610 performs eccentric rotational motion when the shaft S1 rotates.

Operation of the first eccentric piston EP1 due to the gap 'd' is the same as that of the upper piston of the second embodiment.

Industrial Applicability

As is apparent from the foregoing, in the four-in pump according to the present invention, the four eccentric shafts perform eccentric rotational motion by means of the gearing means of the gearing box arranged between the first and the second cylinder blocks, and the pistons respectively mounted on the eccentric shafts perform inscribed eccentric circular motion with different speeds at the volume chambers in the first and the second cylinder blocks, whereby pulsation and vibration are cancelled and whole pulsation and vibration are remarkably reduced.

While the invention has been shown and described with reference to certain preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein

without departing from the spirit and scope of the invention as defined by the appended claims.